LITERAL ENGLISH TRANSLATION OF INTERNATIONAL PATENT APPLICATION NO. PCT/EP2004/012057

ADAPTATION OF AN AUTOMATIC DISTANCE CONTROL TO TRAFFIC USERS POTENTIALLY MERGING INTO THE LANE THEREOF

The invention concerns a process for adapting the distance control for automatic safe following in motor vehicles to traffic users merging into their lane, as well as a device suitable for carrying out the process according to the precharacterizing portion of patent claims 1 and 12.

For increasing the safety and the driving comfort in the guidance of motor vehicles in traffic, these are today increasingly equipped with automatic systems for vehicle following control or safe separation control, by means of which the vehicle automatically maintains a safe separation from a preceding motor vehicle.

An example of a device of this general type is described in European Laid Open Publication EP0605104A1, which device includes a distance sensor, an evaluation unit and an adjustable speed influencing servo device which is under the control of control parameters calculated by the evaluation unit. The distance sensor is, for a example, a millimeter wavelength radar, a lidar or an ultrasound sensor and senses the environment ahead of the road vehicle in order to detect objects or traffic users located therein. The sensor angle is therein generally selected such that objects on adjacent lanes can also be detected. The environment data detected by the distance sensor is transmitted to the evaluation unit, so that, having knowledge of the speed of the equipped vehicle, the speed of the other detected traffic users can be derived. Starting with a safe distance to be maintained, which is generally selected depending upon the speed, a speed-dependent following time t_f is computed. If the equipped vehicle has a higher speed than a recognized preceding traffic user in the same lane, then the following time t_f continuously decreases. If this decrease reaches a preset threshold, then the evaluation unit produces a control parameter or signal which acts on the speed governing servo device in such a manner that the speed of the equipped vehicle is reduced. The distinction as to whether an object or a traffic user is located in the same lane or an adjacent lane occurs herein on the basis of a defined lane breadth. Besides the observation of traffic users in the lane being driven by the equipped vehicle, the evaluation unit determines, using the data from the distance sensor, also the direction of movement of the traffic users in adjacent lanes. If the traffic user moves from an adjacent lane into the defined lane breadth, then the evaluation unit evaluates this traffic user as closest traffic user and controls the speed of the equipped vehicle to be so far below it that the

following time t_f is maintained with respect to this traffic user. This control operation however, in particular in "pincers" movements (hazards closing in from both sides of the equipped vehicle), frequently leads to an abrupt reduction in the speed of the equipped vehicle, since traffic users changing lanes in traffic frequently leave only a very small space between vehicles following behind them in their lane.

In order to attenuate or cushion this type of abrupt speed change, it is proposed in German Laid Open Publication DE10160189A1, to design the rules of behavior of the system for automatic following guidance in such a manner that upon detecting a traffic user in the vicinity of a road merger or junction it takes note of this fact and in connection therewith recognizes that the ahead lying road area approaches the own lane. Subsequently the breadth of the area detected by the distance sensor is broadened, in order to better monitor merging vehicles. On the basis of the recognition that a potential merging vehicle is located in the immediate vicinity, it can be more rapidly and reliably detected and identified as such already in the first detection cycle in which it is recognized by the distance sensor. In this manner a relevant merging vehicle can already be recognized very early, so that more time remains for adjusting the following time t_f and as a result the speed of the equipped vehicle is reduced less abruptly.

For increasing the time available for adjusting the following time t_f and for creating a more comfortable following guidance conforming more closely to the human driving behavior of a vehicle, it is proposed in German Patent DE198 04 944C2 to detect the transverse acceleration of a traffic user located in the adjacent lane and approaching the lane of the equipped vehicle. If herein a transverse speed of a traffic user located in an adjacent lane towards the equipped vehicle is detected, then a conclusion is drawn as to an imminent merging. Accordingly, here also the environment area observed by the distance sensor is widened, in order to better observe this merging vehicle. Since, as a result of the evaluation of the transverse speed, a merging of a traffic user can be recognized on the basis of its change in position already prior to the merging thereof into the lane of the distance regulated vehicle, the control process can be improved and be adapted to the driving behavior of a human motor vehicle operator. In situations in which the merging traffic user however undertakes a relatively rapid lane change, it could also happen that, in the vehicle safe distance guidance described in DE19804944C2, an abrupt speed change of the vehicle could not be avoided.

The task of the invention is thus to provide a process for adaptation of an automatic safe following distance guidance of an equipped vehicle (10) to a traffic user merging into the lane (B), as well as a device suitable for carrying out this process, which avoids abrupt speed changes of the vehicle during the adjustment of the following time to the traffic user, and to better imitate the driving behavior of a human motor vehicle operator.

This task is solved by a process and by a device suitable for carrying out the process according to the characteristics of independent patent claims 1 and 12. Advantageous embodiments and further developments of the invention are described in the dependent claims.

In this new process for adaptation of an automatic following guidance of a road vehicle (10) to a traffic user (20) merging into the lane (B) of the equipped vehicle, objects and traffic users (20) ahead of their equipped vehicle are detected within a detection area (12) originating from a separation sensor. Subsequently, in an evaluation unit the position and speeds of the detected objects and traffic users (20) are determined, in order, beginning with this computed data, to produce control parameters in order to specifically act on servo means for acceleration or deceleration of the equipped vehicle. In inventive manner, for this, in the generation of the control parameters, there is further taken into consideration, in addition to the data regarding the object and the traffic users (20) ascertained in the evaluation unit, information is also accessed from a navigation system describing the layout of the road ahead or a data bank containing information regarding the layout of the road. In the case that it is determined, from the information regarding the further layout of the road, that at least one of the detected traffic users in normal driving behavior would be expected to change to the lane (B) of the equipped vehicle (10), the controlled parameters for the servo means acting on the vehicle (10) are produced in such a manner, that the driving behavior of the equipped road vehicle (10) adapts to the at least one detected traffic user (20) depending upon its vehicle speed and/or position. Included in the typical information regarding the further layout of the road, from which it can be determined, that a traffic user detected therein in the normal vehicle behavior would change to the lane (B) of the vehicle, there belong in particular information regarding junctions, highway on ramps or reduction in available lanes; for example the narrowing of a three lane highway to a two lane highway, in which the vehicles located on the lane which ends must merge into an adjacent lane.

The invention therewith which makes it possible, from recognition of the own vehicle position and with reference to supplemental additional information describing the layout of the

road in a mode and manner looking to the future to already early so adjust the speed of the vehicle that for a potential merging traffic already early place has been provided, which leads to a significantly more harmonious driving behavior. In this advantageous manner the operator of the motor vehicle has the feeling that the system drives by looking ahead in the manner of an ideal human driving behavior.

In the frame work of the invention, for the production of object data from the environment of the inventive system including the motor vehicle, all types of separation sensors known from the state of the art can be employed, in particular advantageously millimeter wavelength radars, lidars or distance resolving camera systems. In particularly advantageously manner, information describing the ahead lying layout of the street can be read from the ADAS (Map Advanced Driver Assistance System), which besides the information necessary for vehicle navigation also includes supplemental information regarding the number of lanes (A, B) and/or markings with respect to on and off ramps (C) on highways or major streets. From this type of map material, as well as from knowing the position of the vehicle, it is possible, using the ADAS-Maps, to relatively precisely determine for example the position of on-ramps, since their location positioning is relatively precise. If, for example, in the layout of the street lying ahead of the equipped vehicle an on ramp is recognized, and if in this on ramp a traffic user is recognized, it can be assumed, that this will merge, according to conventional driving behavior, from the on-ramp onto the thereto adjacent lane. If the equipped vehicle is located on this adjacent lane, then, in contrast to the systems known from the state of the art, the equipped vehicle can be controlled or regulated already before the recognized traffic user even has begun the merging process by suitable adjustment of the servo parameters in its speed in such a manner that space can be made available for the ahead lying merging of the other traffic user.

If on the other hand it is recognized from the information from the navigation system describing the ahead lying layout of the road or from another data bank (for example the ADAS-Map) that an on ramp leads to an additional lane running parallel to the ahead lying lane, then the evaluation unit does not exert influence on the speed of the own vehicle by the production of servo or control parameters. The progression guidance does not react in this type of situation to the recognized traffic user, since in the case of a conventional mode of driving the traffic user is not reliably recognized that the traffic user will carry out a lane change; in such a situation the human driver of the own vehicle will also not react to this traffic user with a change of the

vehicle speed, rather he would maintain the vehicle speed and only carefully observe the driving behavior of the other traffic user.

Of course the functionality of the invention is not limited to the forward looking recognition of merging behavior on on-ramps, but rather can be employed in the same manner also advantageously, for example, in situations in which number of navigable lanes is reduced in the ahead lying layout of the road and wherein the traffic users located on the lane being lost must merge to the remaining lanes.

In the following the invention will be described in greater detail on the basis of illustrative examples and with aide of the figures.

Fig. 1 shows a merging situation on an on ramp on a multi-lane road.

Fig. 2 shows the scene corresponding to Fig. 1, in which vehicles involved in the merging process are located at other positions.

Fig 3 likewise shows a scene corresponding to Fig 1 or 2, in which the vehicles involved in the merging process are again located at other positions.

Fig 4 likewise shows a scene corresponding to Figs. 1, 2 or 3, in which the merging vehicles are located in the dead zone area of the merging vehicle.

A typical merging situation on an on ramp of a multi-lane road is illustrated in Fig. 1. For this a vehicle **10** moves along lane B of a multi-lane road with lanes A and B, in the direction of the directional arrow **11**. The lane C represento an on and off ramp onto the roadway with the lanes A and B. The vehicle **10** is equipped with an inventive system for recognition of merging vehicles, wherein the limitations of, for example, a sensing or detection range of the separation sensor included in the system is indicated by dashed lines **12**. In the examples shown in Figs. 1 through 4 the sensing area of the separation sensor is so arranged that it overlaps wide areas of lanes A, B, and C. A vehicle **20** is moving along lane C, which is located in the sensing area **12** of the separation sensor and therewith is detected by the inventive system. Based on the assumption of a typical driving behavior it is then to be presumed, that the vehicle **20** will change from lane C to lane B along a trajectory **21a** or **21b** or **21c** (or a similar trajectory). Which of the possible trajectories is selected by the driver of the vehicle in the course of his change or merging process cannot be predicted in a situation as illustrated in Fig. 1, since the vehicle is still driving straight ahead and therewith no significant transverse movement can be measured. By

means of the evaluation of the sensor data of the separation sensor however the relative speed of the vehicle **20** can be measured in reference to the own vehicle **10**.

In order to allow vehicle **20** an optimal, interference-free merger process it is possible in advantageous manner in those cases, in which the speed of the at least one detected traffic user **20** is exceeded by the speed of the equipped vehicle **10**, to so adapt the driving behavior of the own vehicle **10** to that of the traffic user **20**, that by a suitable adjusting of the servo parameter the speed of the own vehicle **10** is reduced to the realm of the speed of the traffic user **20**. In this manner, the distance between the two vehicles remains essentially constant, so that the driver of the equipped vehicle **10** does not experience an uncomfortable approaching to the vehicle **20**, and also the operator of the vehicle **20** is implicitly telegraphed the possibility of a safe merger.

In order to optimize the driving behavior of the vehicle **10** in its breaking behavior, the relative speed of the vehicle **20** relative to vehicle to **10** should be taken into consideration in determining the servo parameters for the vehicle brake system. Therein it is advantageous when the separation of the equipped vehicle **10** to the at least one detected traffic user **20** is so large, that the reduction and speed of the equipped vehicle **10** occurs with moderation. Here the operator of the equipped vehicle **10** is not disturbed by oscillations in distance between the vehicles or a moderate approaching of the own vehicle to the other vehicle **20** and this behavior corresponds essentially to his own natural driving behavior. In those cases, as shown for example in Fig. 2, in which the distance of the equipped vehicle **10** to the at least on detected traffic user **20** is relatively small and wherein he in accordance with a conventional driving behavior would quickly carry out a change in lane maneuver, the reduction and speed of the own vehicle **10** can advantageously occur rapidly. In the here shown example the other vehicle **20** is located close to the end of the on ramp, so that, in accordance with conventional driving behavior, it can be presumed, that the merging maneuver from lane C to lane B would occur very soon along trajectory **22**. Alternatively to a rapid dropping of the vehicle speed of the own vehicle **10** this could in advantageous manner also be so controlled, that a change in lane to an adjacent, away from the detected traffic user **20** (here: lane A) is carried out along for example trajectory **13**. Such a behavior, the avoidance of danger, corresponds to the natural behavior of the vehicle operator and is thus not found to be a cause of concern by the operator.

If this type of change in lane occurs completely automatically, it should be ensured, that prior to the change in lane to the lane opposite to the traffic user **20**, the adjacent lane A is checked for avoidance of accidents by means of a sensor system for monitoring adjacent lanes such as a blind spot monitoring system, to ensure that a safe change in lane of the own vehicle **10** to lane A is possible.

The result of a checking and monitoring of this type of the occupancy condition of a possible evasion lane can lead to a decision regarding suitable means for reaction to an eminent merging vehicle **20**; that is, it can be decided whether the operator of the vehicle **10** would prefer a rapid breaking of his own vehicle or whether a deviation to lane A would be considered more natural and comfortable.

In Fig. 3. a traffic situation is illustrated, in which the separation of the equipped vehicle **10** to the at least one traffic user **20** in the detection area **12** is relatively small, it however still has time remaining for a lane change in accordance with the conventional driving behavior, the speed of the equipped vehicle **10** is not reduced since vehicle **10** moves in general substantially faster than the other vehicle **20,** thus it will speedily overtake this, so that the operator of the other vehicle **20** can merge behind vehicle **10** onto lane B without problem. In an advantageous manner it is however also conceivable, in a situation of this type, to moderately increase the speed of the own vehicle **10**, if the traffic situation or the traffic regulations or a setting of the cruise control system (Tempomat, Distronic) permit this. In this manner, on the one hand, the equipped vehicle **10** distances itself substantially more rapidly from the potential dangerous situation and, on the other hand, the operator of the other vehicle **20** is given more time for merging, since the lane B is more rapidly opened. If vehicle **10** however has accelerated, in advantageous manner the speed thereof should, after passing the other traffic user **20,** again be reduced to the speed at which it operated prior to overtaking. By this return controlling of the speed, the vehicle **10**, despite the merger maneuver of an another vehicle onto the lane of the equipped vehicle, continues on its way with the accustomed behavior.

Fig. 4 shows a further merger situation of an on ramp. Herein the own vehicle **10** moves along along lane B of a multi-lane highway with lanes A and B in the direction of the indicating arrow **11**. On the same lane A there is supplementally a vehicle in traffic **30**, which moves in the

direction of the indicating arrow **31**. A further vehicle **20** moves along lane C, this is however located in the blind area of the equipped vehicle **10** and is detected by a blind angle monitoring system integrated in the equipped vehicle **10**. Under the assumption that the other vehicle **20** is moving faster than the equipped vehicle **10**, it is to be presumed, that the other vehicle **20** will change lane from C to lane B along the trajectory **24** or similar trajectory between the vehicles **10, 30**. In the case that the distance between the vehicles **10, 30** is large or that no preceding vehicle **30** is present, a moderate reduction of the speed of the equipped vehicle **10** suffices, so that the other vehicle **20** can merge with a safe distance ahead of the equipped vehicle **10**. A substantial speed reduction is herein brought about by giving no gas for a short time. In a case that the vehicles **10, 30**, move along with approximately the same speed and follow close to each other, space must be provided for the merger of vehicle **20**. In the case that it is determined from the vehicle **10** by means of a blind spot monitoring system that no vehicular traffic is located on lane A, it can be presumed, that the vehicle **20** immediately after merging on to lane B will continue changing lane to lane A, so that a more forceful engagement of brakes can be extended for a short while in vehicle **10**. In contrast, in the case that the adjacent lane A is already occupied, a stronger actuation of the breaks is brought about in vehicle **10** without delay.

In particularly advantageous manner the inventive process and the inventive device allow themselves to be used to merge from a lane traveled by a vehicle **10** equipped according to the invention to an adjacent lane upon which other traffic users are located. Herein it is decided, in particular with access to environment information regarding the adjacent road layout, whether the vehicle **10** should merge ahead of or after a particular traffic user traveling there. Depending upon this decision one sets the speed of the own vehicle either above or below the speed of the concerned traffic participant by suitable selection of the adjustment parameter for the servo means for acceleration or braking of the own vehicle, so that a safe merger procedure into the adjacent lane is safely carried out representing a far-sighted manner of driving.